Herschel Photodetector Array Camera & Spectrometer

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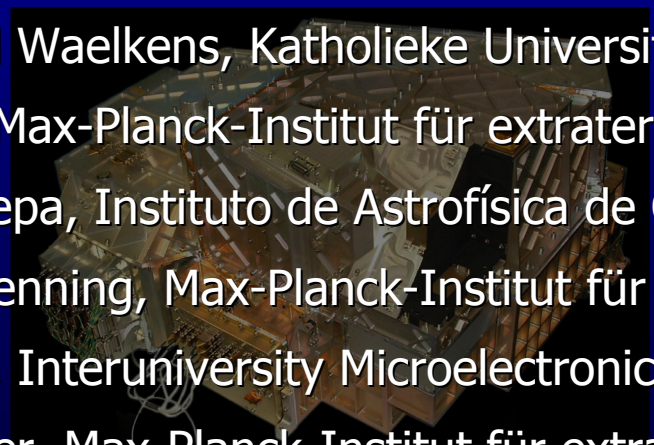
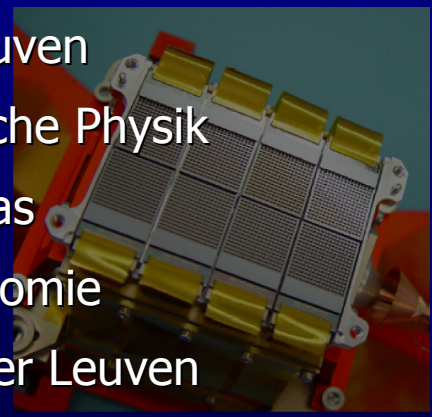
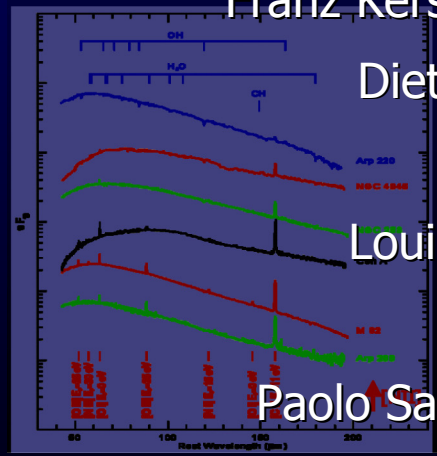
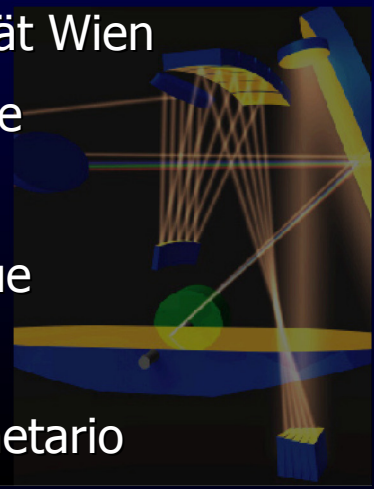
Pierre Royer, Katholieke Universiteit Leuven

Paolo Saraceno, Istituto di Fisica dello Spazio Interplanetario





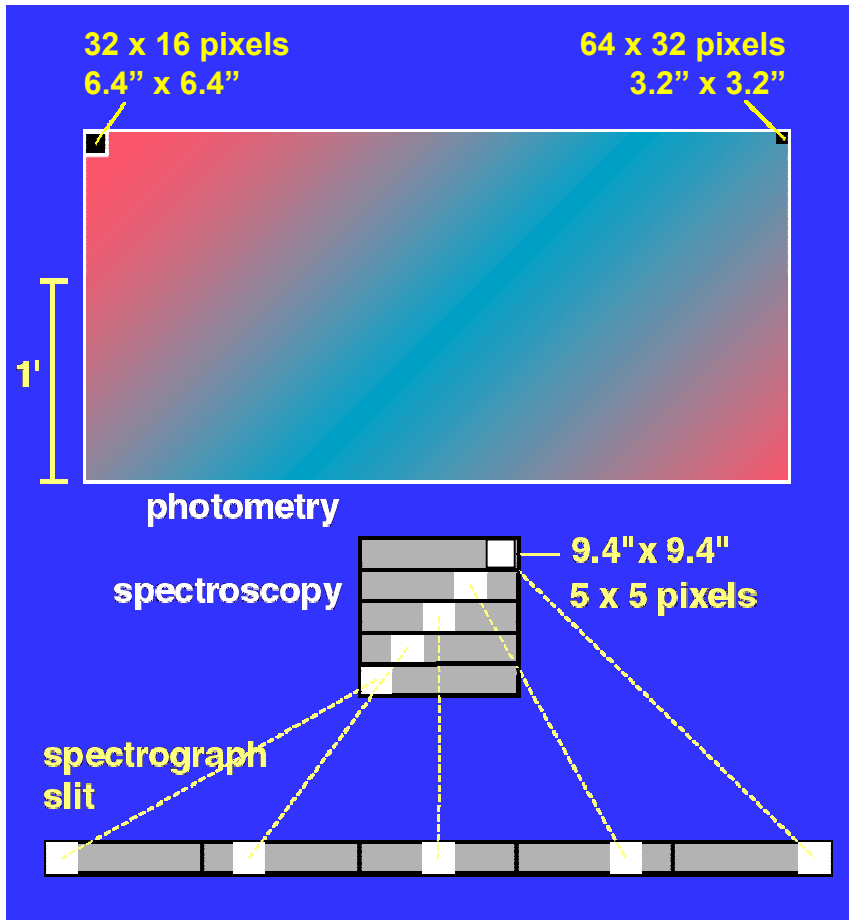




Instrument Concept

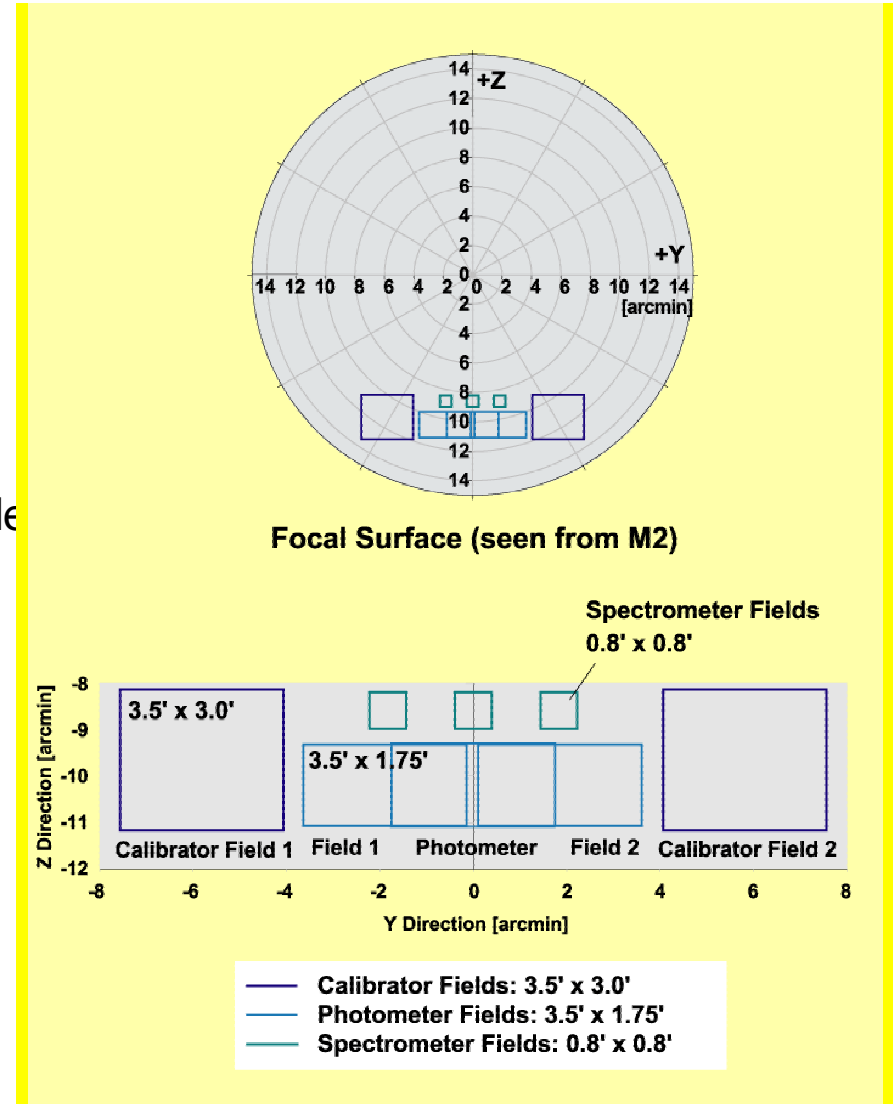
- **Imaging photometry**
  - two bands simultaneously (60-85 or 85-130 μm and 130-210 μm) with dichroic beam splitter
  - two filled bolometer arrays (32x16 and 64x32 pixels, full beam sampling)
  - point source detection limit ~3 mJy (5σ, 1h)
- **Integral field line spectroscopy**
  - range 57 - 210 μm with 5x5 pixels, image slicer, and long-slit grating spectrograph (R ~ 1500)
  - two 16x25 Ge:Ga photoconductor arrays (stressed/unstressed)
  - point source detection limit 3…10 x10^{-18} W/m^2 (5σ, 1h)

Focal Plane Footprint

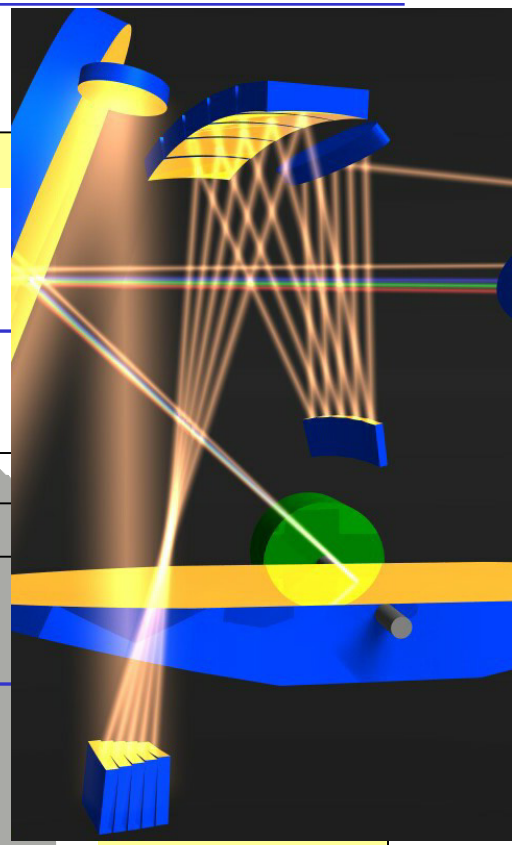


Observing Modes

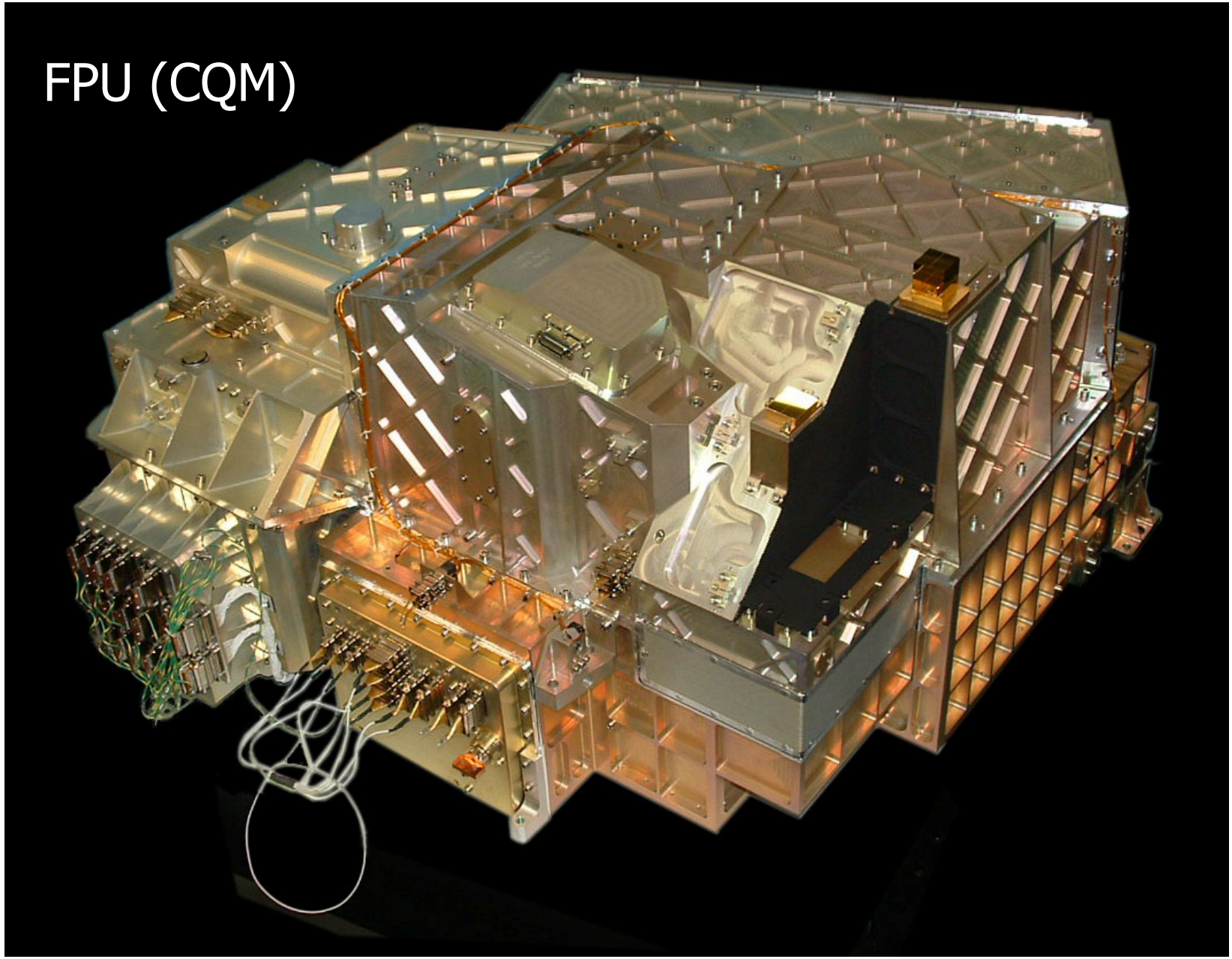
- Combinations of *instrument modes* and *satellite pointing modes*
- Instrument modes:
  - dual-band photometry
  - single-band photometry
  - line spectroscopy
    - observation of individual lines
  - range spectroscopy
    - observation of extended wavele
- Pointing modes:
  - stare/raster/line scan
  - with/without nodding
- Internal chopper
  - background subtraction
  - calibration



FPU/Optics

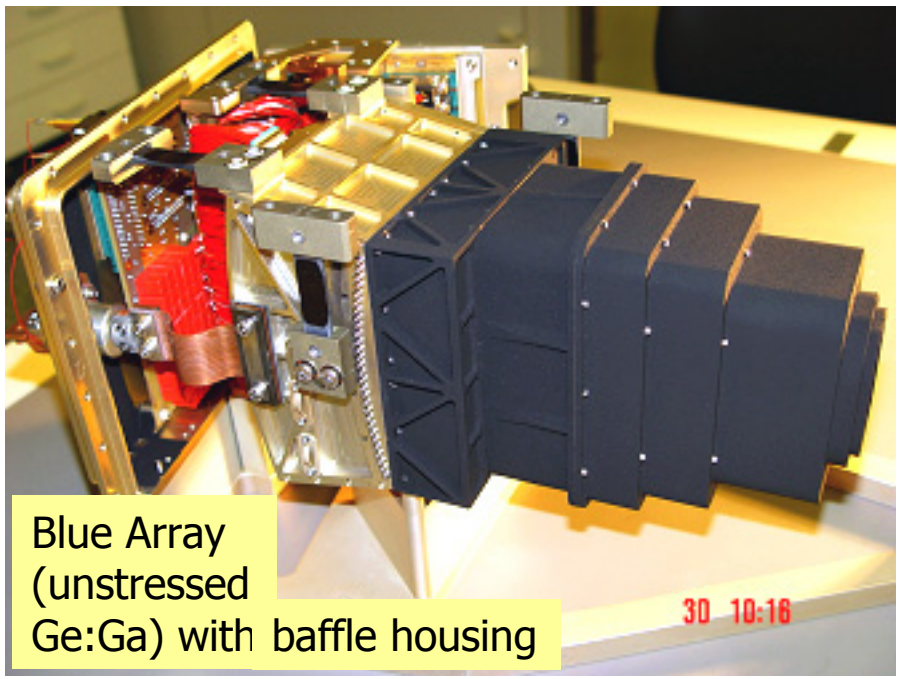


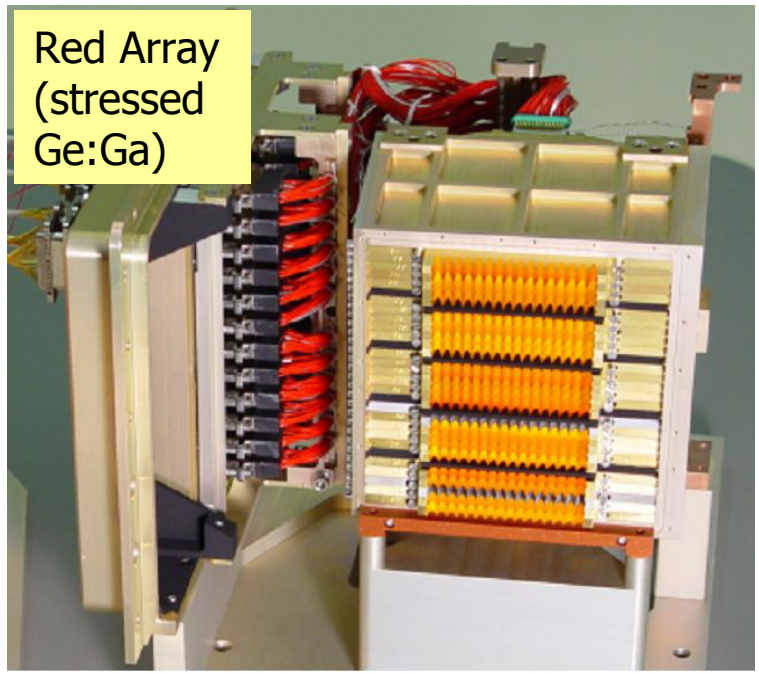
Photometer Optics
Filter Wheel I
Blue Bolometer
0.3 K Cooler
Red Bolometer
sGeGaDetector Red Spectrometer
Chopper
Calibrator I and II
Filter Wheel II
Calibrator Optics
GeGa Detector Blue Spectrometer
Entrance Optics


FPU (CQM)

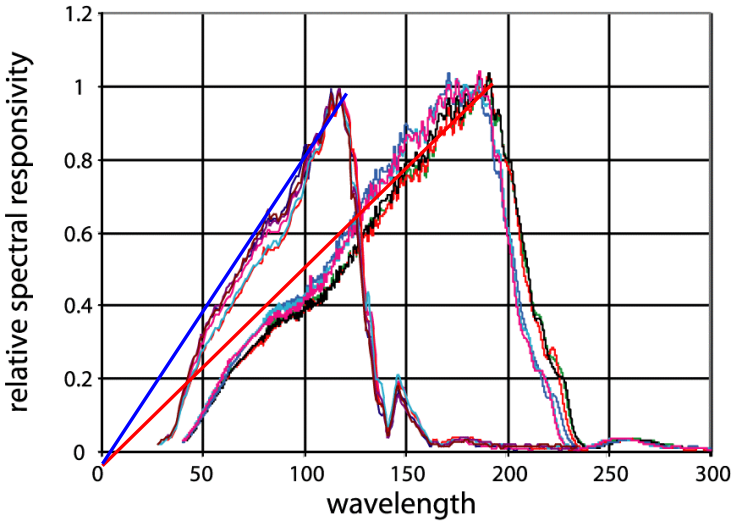
Photoconductor Arrays for Spectroscopy

- 16x25 pixel filled arrays
  - extrinsic photoconductors (Ge:Ga, stressed/unstressed)
  - 25 linear modules of 16 pixels
  - integrated cryogenic readout electronics (CTIA/multiplexer)
  - background-noise limited performance expected

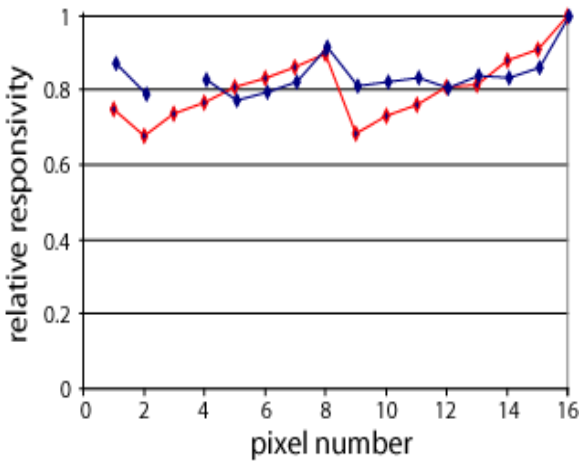


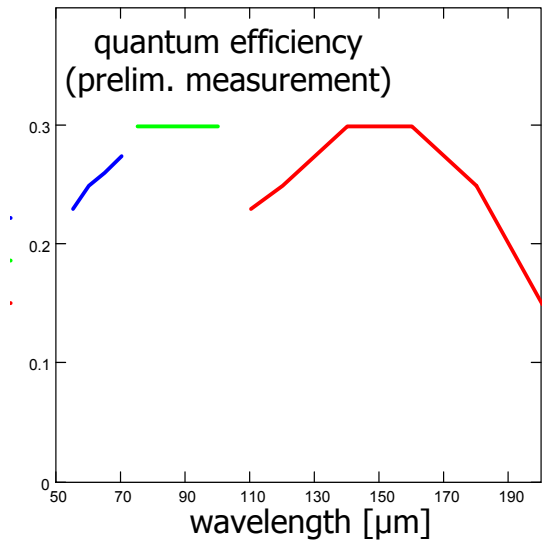


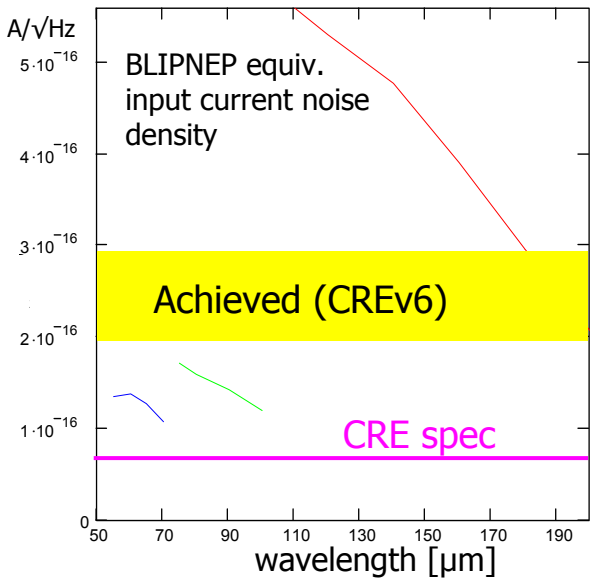
Photoconductor Performance Tests



- Homogeneous relative spectral responsivity within module
- Homogeneous relative photometric responsivity within module
- Nominal detective quantum efficiency
- Readout noise above spec – CRE under redesign

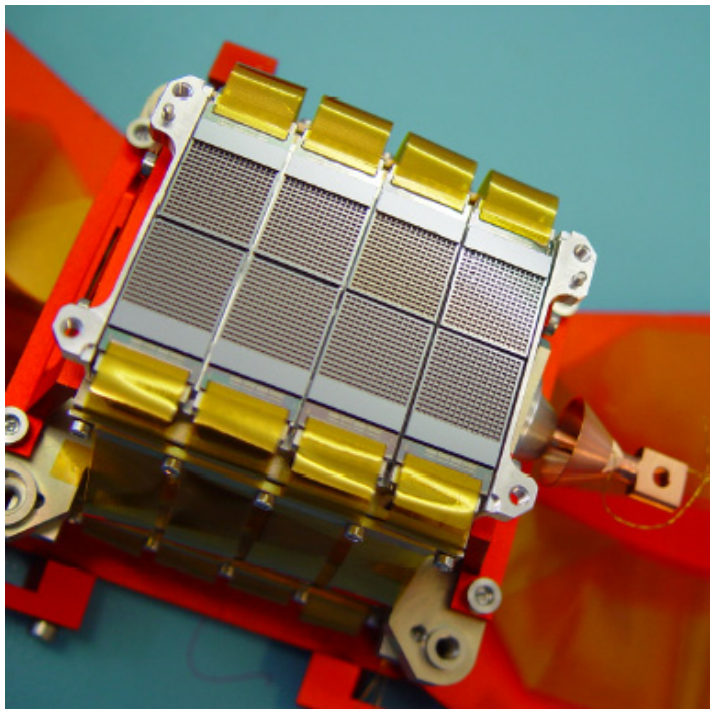




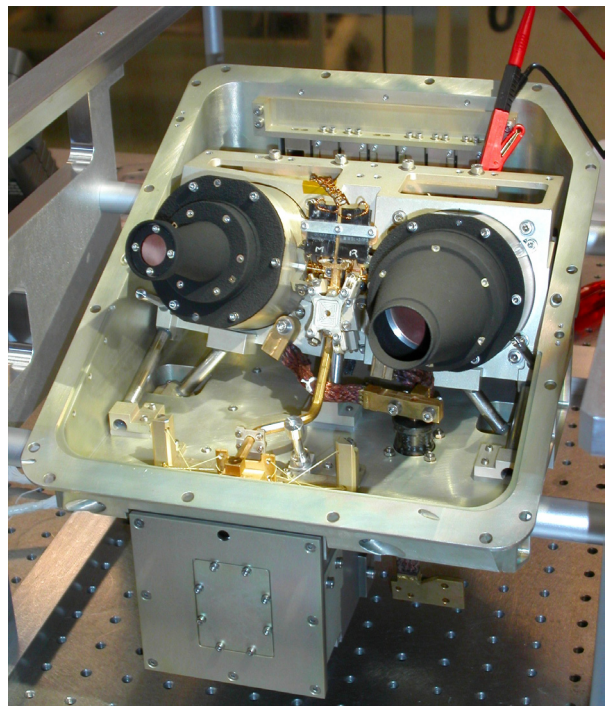


Bolometer Arrays for Photometry

- Filled arrays: 64x32 pixels (blue) and 32x16 pixels (red)
- Bolometers and multiplexing readout electronics operating at 0.3K
- Internal 0.3K sorption cooler with 48h hold time
- Background-noise limited performance demonstrated

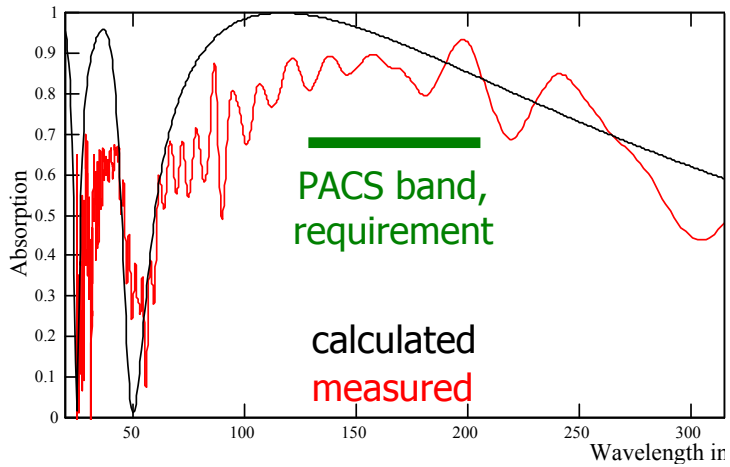


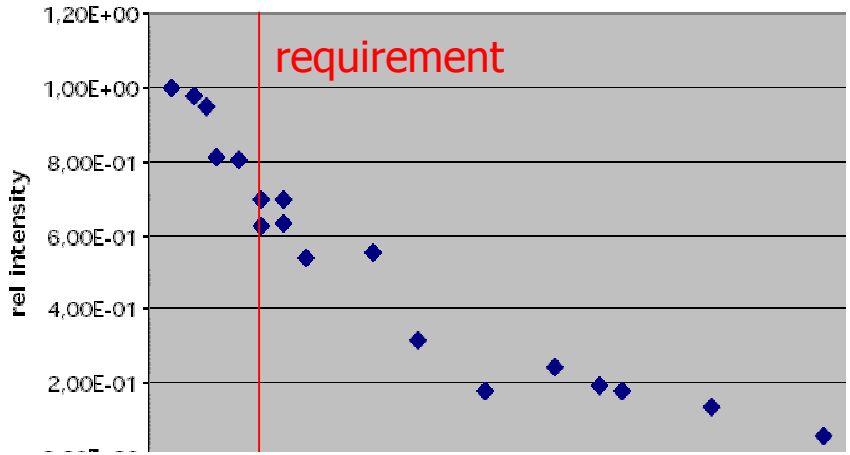
Blue
focal plane



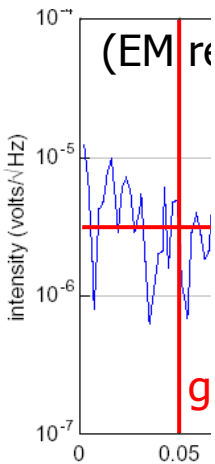
Bolometer unit
with blue + red
focal planes and
0.3K cooler

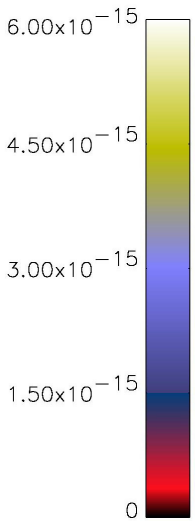
Bolometer Performance Tests

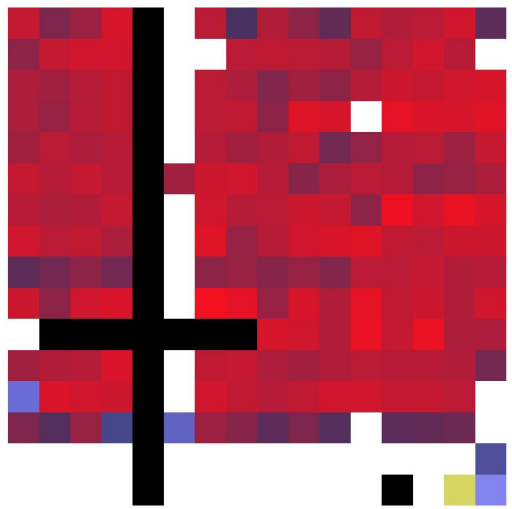




- Efficiency >80%
- Detector bandwidth ~4 - 5 Hz
- "1/f" noise "knee"/ stability: no signifi-cant increase down to 0.05 Hz
- QM deteriorated by contact problems

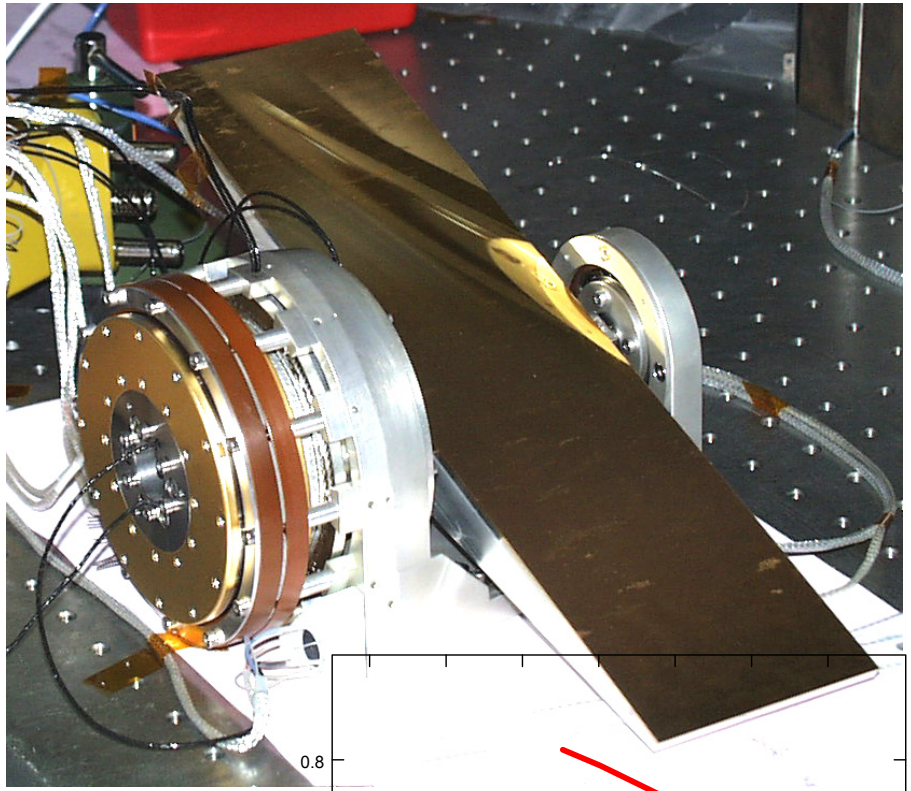


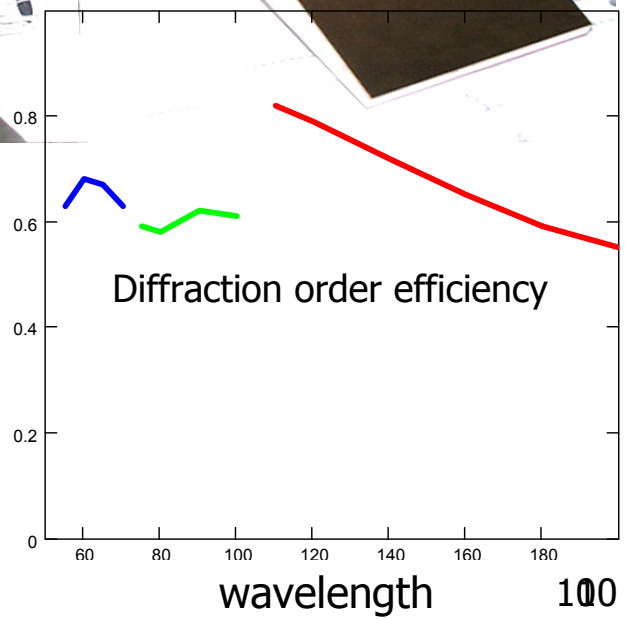




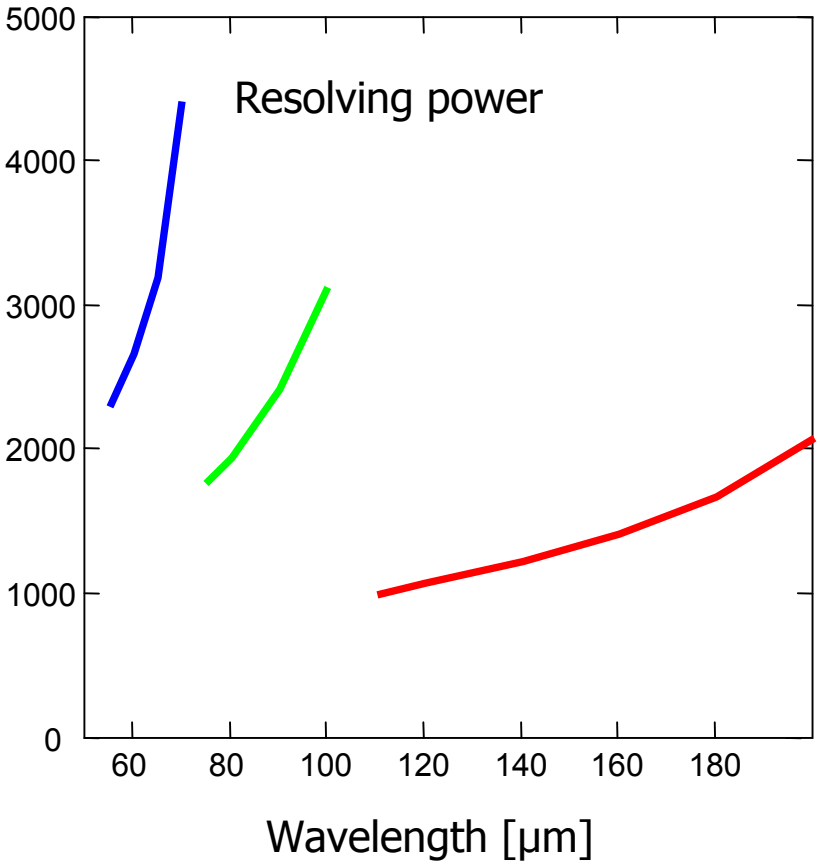
Diffraction Grating

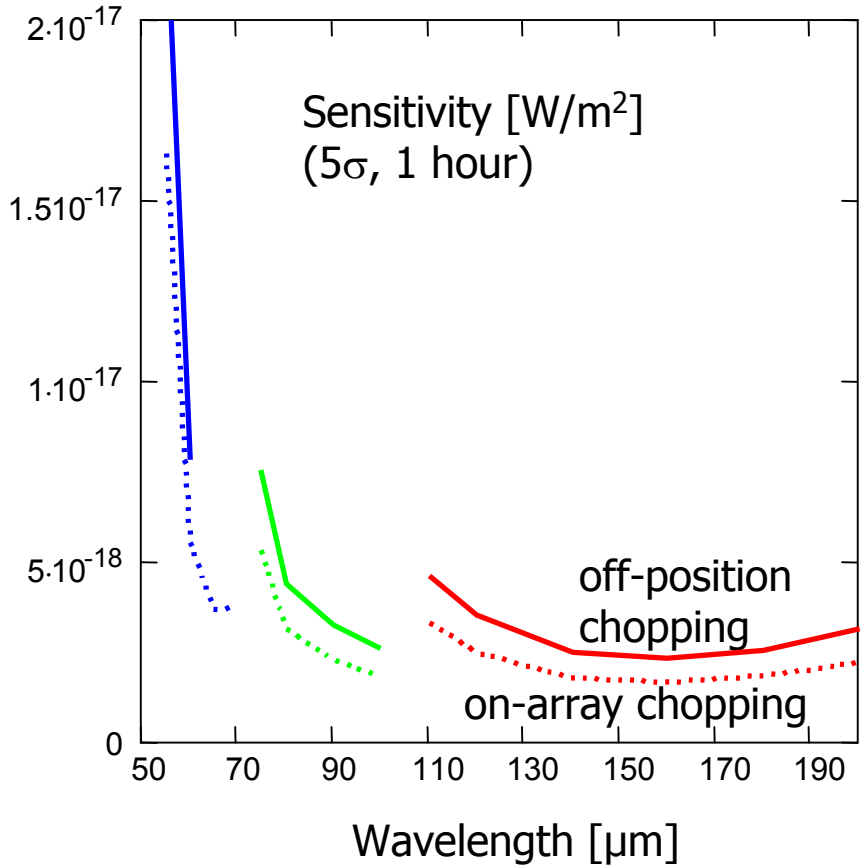
- Diamond ruled reflection grating
- Optical size 320 x 80 mm
- Used in 1st, 2nd, and 3rd order, angle range 48°±20°
  - 1st order (red detector) 210 - 105 µm
  - 2nd order (blue detector) 105 - 72 µm
  - 3rd order (blue detector) 72 - 55 µm
- Groove profile optimized for highest efficiency over all 3 orders
- Cryogenic torquer motor



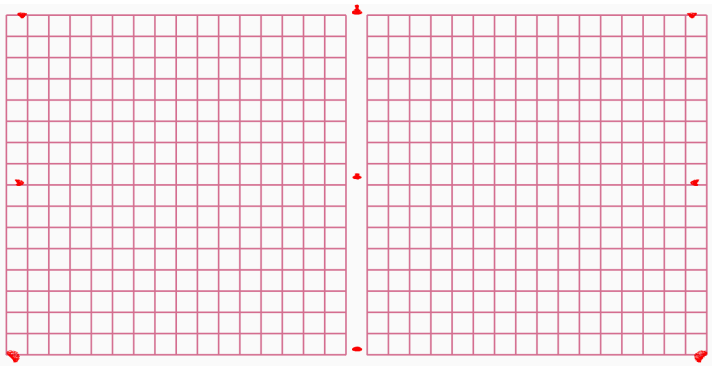


Predicted Spectrometer Performance





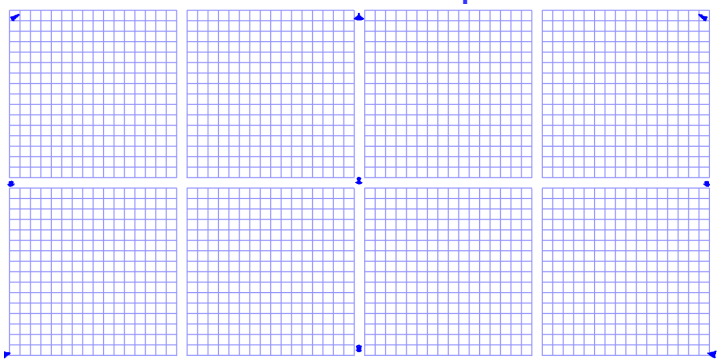
Predicted Photometer Performance



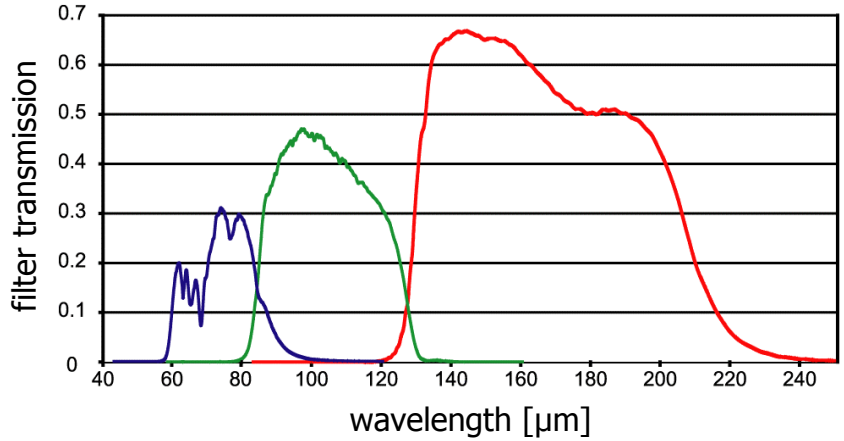
- Strehl ratio 0.99
- Distortion < 1 pixel

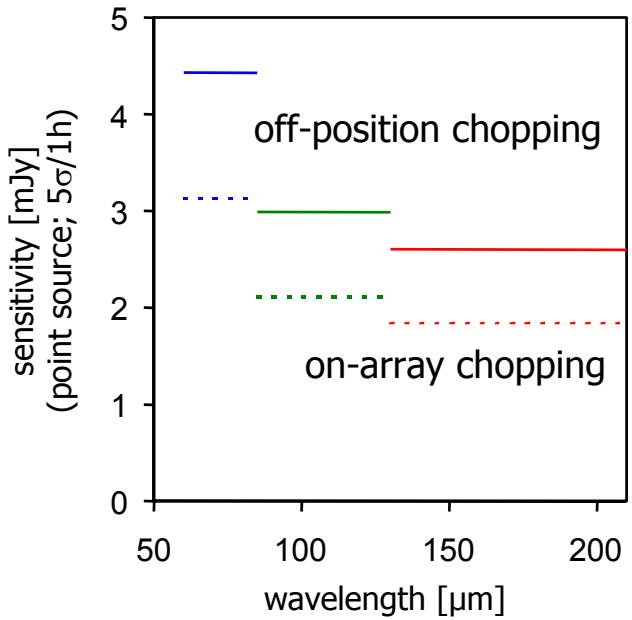
Image Quality

- Strehl ratio >0.95
- Distortion < 1 pixel



Photometric Bands





(10'x10' in 1 day)

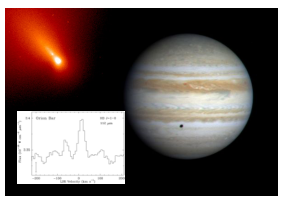
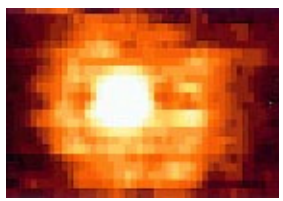
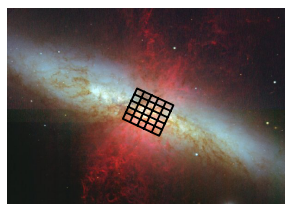
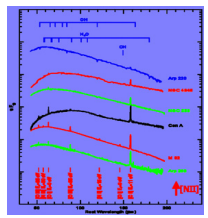
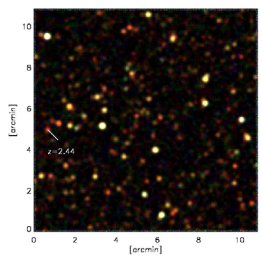
Sensitivity

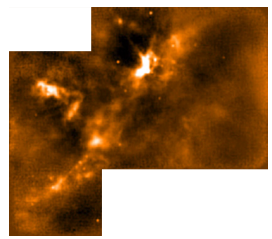
Science with PACS

- The opening of the 60-210 μm window by PACS to sensitive photometry and spectroscopy at high spatial resolution will address a wide range of key questions of current astrophysics concerning the origins of stars, planetary systems, galaxies, and the evolution of the Universe
- Most of the energy released e.g. in starbursts or AGNs is absorbed by interstellar dust (which prevents observation at shorter wavelengths) and re-emitted in the far infrared and sub-mm domain
- Besides dusty objects also cool and/or distant objects have their emission peak in the far-IR

Science with PACS

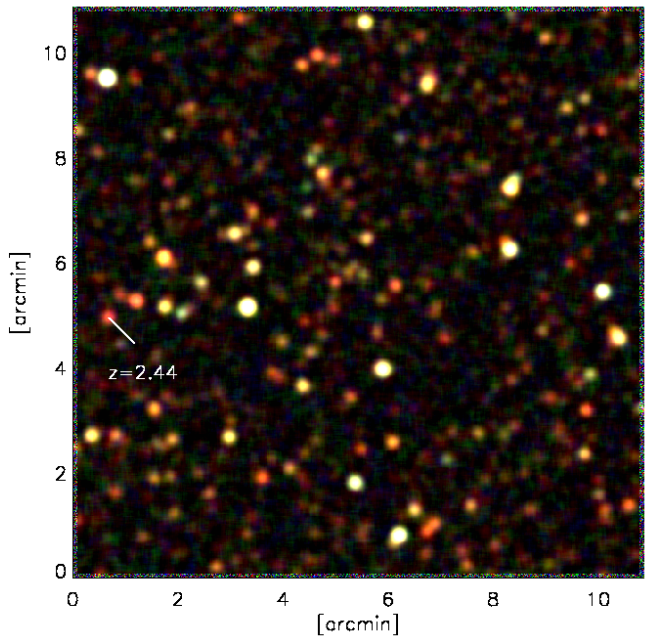
- The far-IR also contains many spectral lines from atoms, ions and molecules. Largely unaffected by extinction they provide detailed information on UV radiation, density, temperature, velocities and abundances of ionized and neutral components of interstellar and circumstellar gas
- PACS is also intended to be an important driver for other projects which will explore adjacent spectral regions, such as JWST in the near/mid IR and ALMA in the mm domain



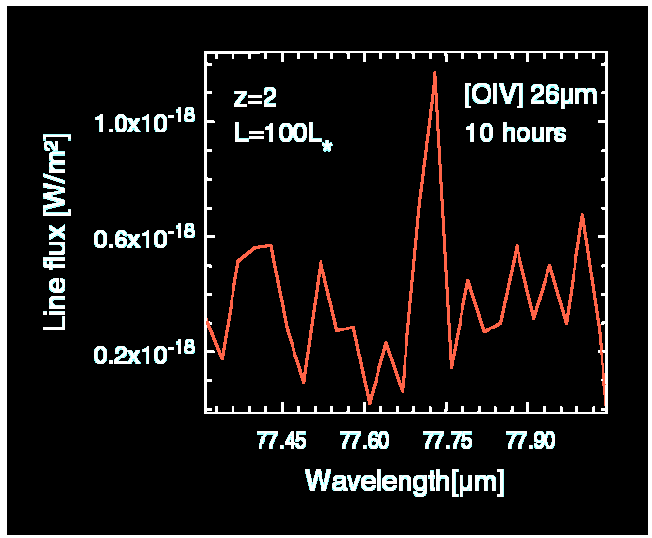
Science with PACS - *Examples*

What is the cosmic history of star formation and AGN activity?



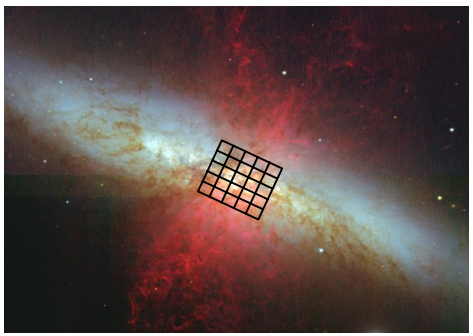
Simulated deep PACS survey of 10^{-5} sr at 75, 110 and 175 μm (false colors) to a 1σ limit of ~0.5 mJy (50h). Deepest sources are at z~3.

- Deep multi-band photometric surveys and spectroscopy of objects at the peak of cosmic star formation (z=1...3). At these redshifts the PACS wavelength range samples the emission peak of actively star forming galaxies.



Science with PACS - *Examples*

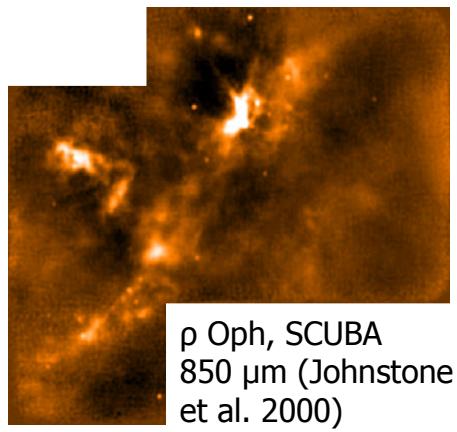
How do stars form out of the interstellar medium?



M82 (Subaru/FOCAS) with the PACS spectroscopy FOV overlayed

- Local galaxies: photometric and spectral line mapping for detailed, spatially resolved studies of star formation on galactic scales. PACS will be able, e.g., to trace for the first time the different warm/cold dust components in arms, interarm regions, star forming complexes, etc.

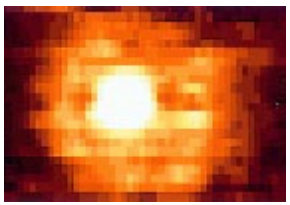
- Photometric surveys of nearby molecular clouds: search for protostars, pre-stellar condensations, young stars (all young stellar objects emit mainly in the wavelength range of PACS/Herschel). Resolve debris disks around young stars with planetary systems in formation.



ρ Oph, SCUBA 850 μm (Johnstone et al. 2000)

Science with PACS - *Examples*

How does stellar mass loss influence the ISM chemistry?

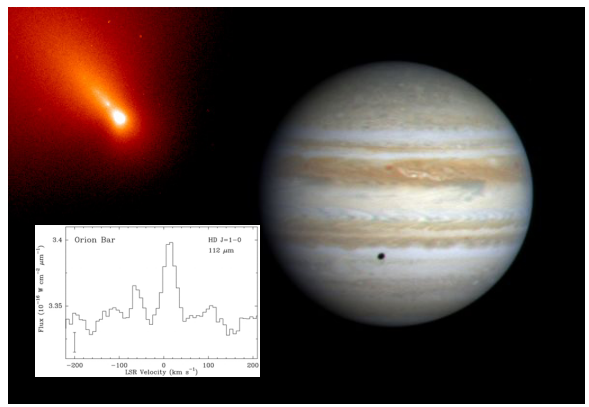


The carbon star YCVn. ISOPHOT 90 μm map (Izumiura et al. 1996)

- Photometric mapping and spectroscopy (e.g. CO, H_2O, OI) of the circumstellar matter in evolved objects. Spatially resolving envelopes and shells of evolved stars will help to better understand mass loss and the latest phases of stars.

What has been the history of our solar system?

- Imaging of faint comets and asteroids
- Spectroscopy of giant planet atmospheres: composition, profile, origin of water
- HD line: D/H ratio in Solar System bodies and our close galactic environment probing the composition of pre-solar grains



Emerging PACS GT Program (~2000 h)

- Circumstellar Matter in Evolved Objects
  - AGB, P-AGB, PNe, RSG, WR, LBV, SNe
  - Combined photometry/spectroscopy
- Star Formation
  - Large-scale imaging survey of molecular clouds
  - Detailed investigation of pre-stellar cores and protostars
  - Mineralogy (spectroscopy) and imaging of YSO and debris disks
- Survey of the Extragalactic Sky
  - Wide survey covering in total a few square degrees at ~ the 170μm confusion limit
  - Deeper surveys approaching or reaching the confusion limit at 110 and 75 μm over smaller regions
  - Lensing cluster assisted observations

PACS GT Program (cont.)

- Dusty High-z Quasars
  - Photometry of highest redshift ($4 < z < 10$) quasars
  - Spectroscopy of selected (lensed) high-z objects
- Local Galaxies Programs
  - Luminous IR galaxies
  - Low metallicity dwarf galaxies
  - Nearby (normal) galaxies (spirals, extended disks, barred, …)
  - Dust in ellipticals
  - Galaxy Clusters, intercluster dust